

Robotic Assembly of Digital Structures using Deployable Elements

Completed Technology Project (2013 - 2017)



Project Introduction

Abstract The massive energy expenditure required to transport objects out of the gravity well necessitates maximum utility-for-weight for all cargo intended for missions to space. I propose a manufacturing scheme and robotics platform that addresses this necessity by generating robotic systems capable of meeting a diverse array of mission objectives but derived from a single reel of specialized material. Inspired by ribosomal assembly, this system will begin with a long strip of a resilient but deformable material that has control structures and actuators embedded in it. A printer will then fold this feed into a complex shape that is capable of moving through and interacting with its environment. Structures generated from this printer will contain on the order of 1000 individual folds, enabling forms of high complexity, and the proposed system is planned to generate these forms in short (under 10 minute) time scales. **Impact** The core of this work aligns with two lines of inquiry as specified by the NASA Space Technologies Roadmaps and Priorities: Technology Area 12: Materials, Structures, Mechanical Systems, and Manufacturing and Technology Area 07: Human Exploration Destination Systems. In the former, the development of a flexible manufacturing scheme capable of producing a robotic system tailored to the current mission objective is central to the description of Technology 12.4.2, Intelligent Integrated Manufacturing and Cyber Physical Systems (Manufacturing). In the latter case, it is the integration of the complete system into the human environment that will allow this technology to play a vital role in future missions to space. The robots generated using this scheme could be employed in the creation and maintenance of intelligent environments as described in Technology 7.4.3, Smart Habitats. These environments will form a robust ecology of robotic systems, printing machines to accomplish simple tasks then recycling the components back into the source feed to conserve resources. **Methodology** I will develop three important lines of inquiry simultaneously: the design of a robust and specialized feed material that contains deformable elements and control structures, a printer capable of mutating this material into complex, three-dimensional patterns, and a computational optimization scheme for the identification of sequences of folds that produces structures capable of delivering meaningful work. **Feed Material Design:** For the feed material, I will design a platform consisting of a structurally sound but deformable material in which control structures have been embedded. These control structures will include such components as servos that provide torque and sensors that provide information about the environment. **Printer Construction:** Assembling a functioning robot from this feed material will require the design and implementation of a printer that is capable of deforming it into a sequence of folds that represent a useful configuration. The printer will take the ribbon and use a hydraulic press to bend the mutable portions with one of four folds. Using a combination of these four mutations, this printer will be able to generate a wide variety of possible structures for a given length of material. **Optimization Scheme:** Given an unmodified feed material that contains a specific sequence of control structures, I plan to find a large number of viable



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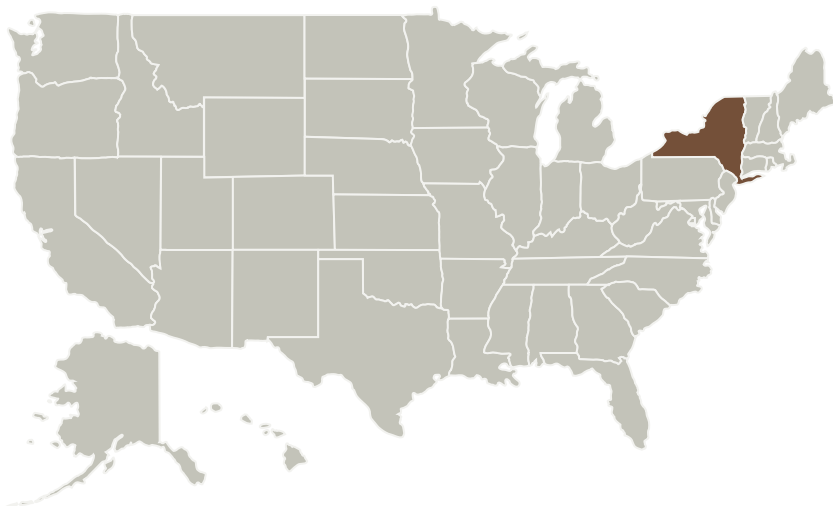


morphologies that can be generated from this one sequence. In this vein, I plan to pair the manufacturing process with a robust physics simulation capable of predicting the general behavior of a configuration before it is printed. Using an optimization technique with a novel representation to produce interesting fold patterns, I will test the efficacy of these conformations in the simulation first, then print the best performers to see how well these designs translate into the physical domain.

Anticipated Benefits

This flexible manufacturing scheme is capable of producing a robotic system tailored to the current mission objective. The integration of the complete system into the human environment will allow this technology to play a vital role in future missions to space. The robots generated using this scheme could be employed in the creation and maintenance of intelligent environments. These environments will form a robust ecology of robotic systems, printing machines to accomplish simple tasks then recycling the components back into the source feed to conserve resources.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Cornell University	Lead Organization	Academia	Ithaca, New York

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Cornell University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Mason A Peck

Co-Investigator:

Daniel W Cellucci

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Primary U.S. Work Locations

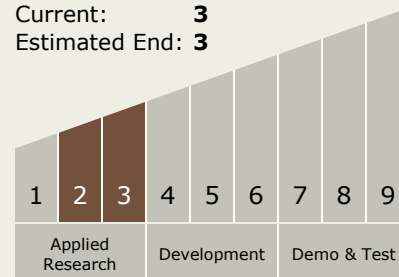
New York

Project Website:

<https://www.nasa.gov/directorates/spacetech/home/index.html>

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
 - └ TX12.4 Manufacturing
 - └ TX12.4.1 Manufacturing Processes

Target Destinations

The Moon, Mars